

NASA Aerospace Battery Workshop 2011

**Updated Life Test data of Next Generation Lithium-ion Cell
for Satellite Applications**

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- **GS Yuasa's heritage cell test data (LEO&GEO)**
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Background

- **Status of the heritage cell**
 - **GS Yuasa started the development of Lithium ion cell for space application in 1997.**
 - **GS Yuasa has 50Ah, 100Ah and 175Ah cells in the basic lineup. Their chemistry (Generation 2) has been fixed since 1999.**
 - **GS Yuasa will continue to supply them.**

Real time LEO DOD25% cycling test

Cycling condition

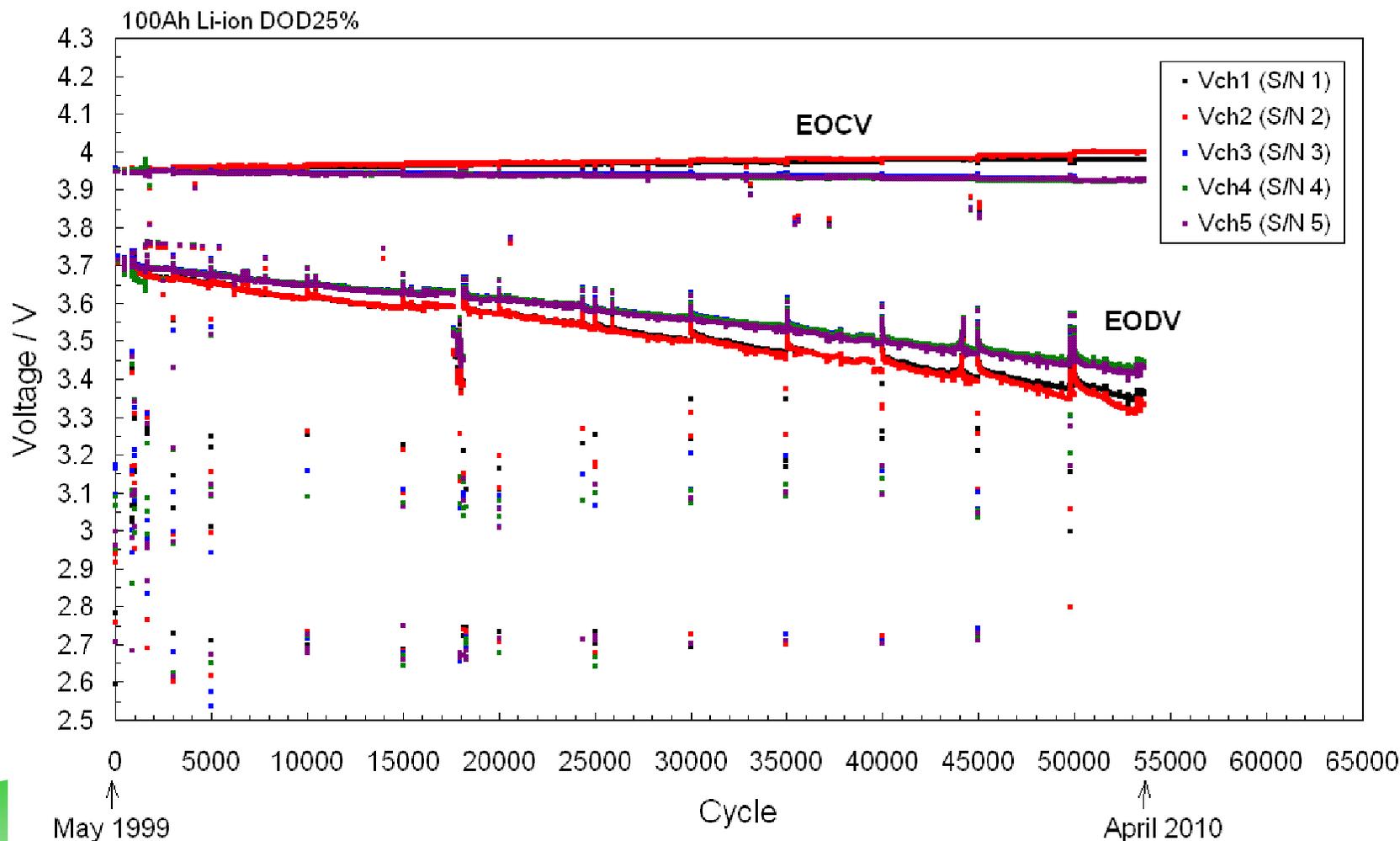
- Charge : 50A/3.95V (CC/CV) for 60min
- Discharge : 50A CC 30 min
- Temperature : 15 degrees C

Capacity check condition (at 15 degrees C)

- Charge : 50A/3.95V (CC/CV) for 60min
- Discharge : 50A to 2.75V

- Charge : 10A/3.95V (CC/CV) for 16 hours
- Discharge : 50A to 2.75V

25% DOD real time LEO life cycle test result of the Gen.2 cells



This data was obtained by JAXA

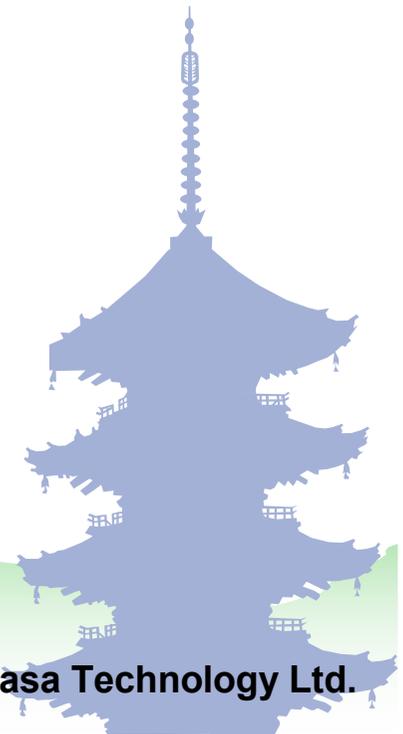
Semi-accelerated GEO (Max.70%DOD)

Test condition

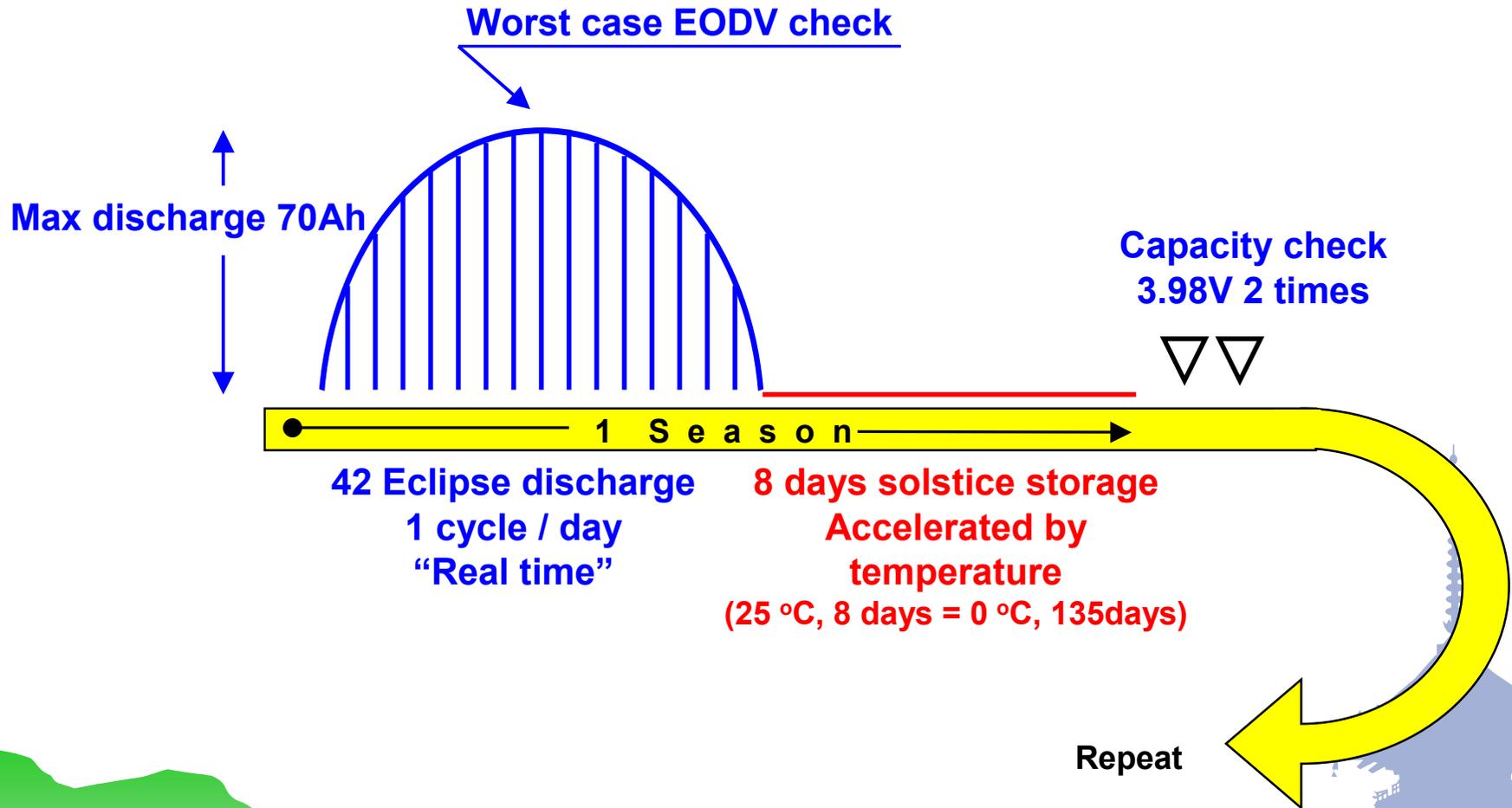
- Season consists of (1)and (2), which simulate eclipse season and solstice season, respectively.
- (1) 42variable DOD cycles (Max.DOD70%, Ave.DOD58% at 15degrees C)
- (2) 8days storage at SOC 50% at 25degrees C
- (Corresponding to 6months storage at 0degrees C)

Capacity check condition (at 15 degrees C)

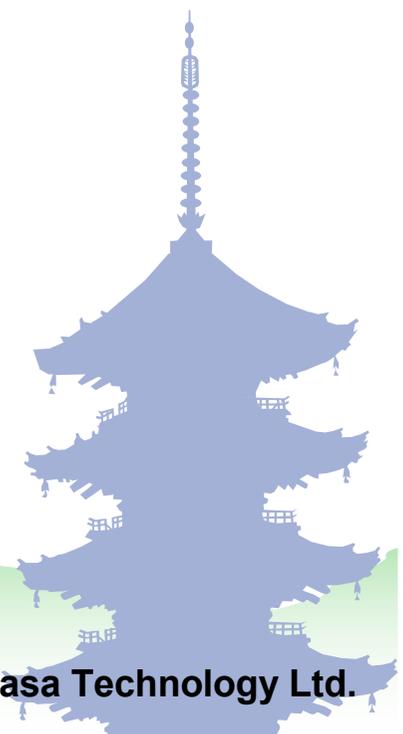
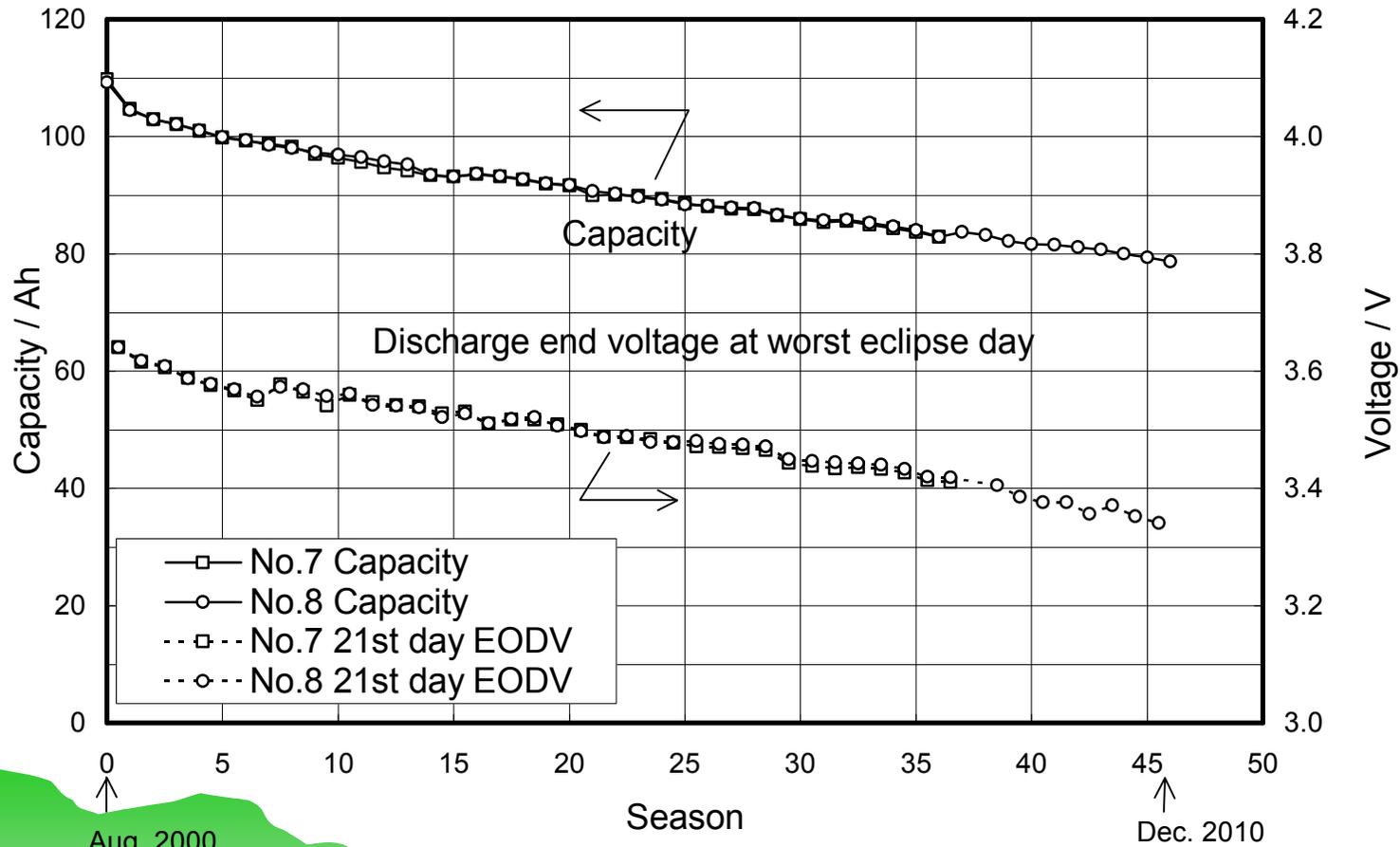
- Charge : 10A/3.98V (CC/CV) for 20 hours
- Discharge : 58.0A to 2.75V



Semi-accelerated GEO (Max.70%DOD) (continued)



Max 70% DOD simulated GEO life cycle test result of the Gen.2 cells



Background (continued)

- **Why is the next generation cell needed?**
 - **GS Yuasa decided to meet the increasing demands of customers.**
 - **Longer mission life**
 - **Higher specific energy**

Key improvements

1) Higher capacity retention

- SEI formation of improved carbon material is very small.
- Improved electrolyte solution drastically suppresses SEI growth.

2) Smaller DCR growth

- Improved positive active material drastically suppresses DCR growth.

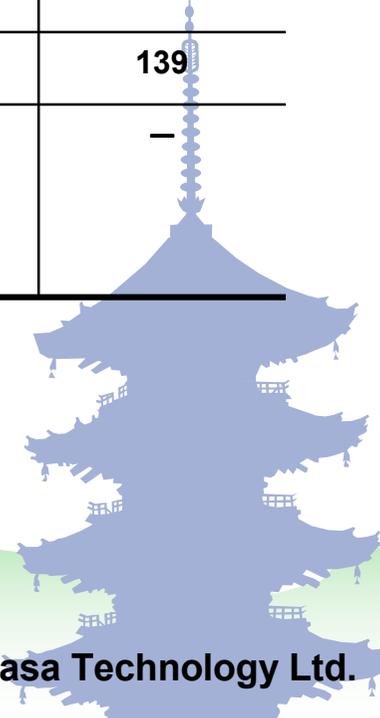
3) Increase of capacity

- Application of thinner separator
- Increment of initial EOCV up to 4.10V from 3.98V.

Target specifications of the next generation cells

Item		Next generation cell, standard type			(Ref.) Heritage cell (Gen. 2)	
		110Ah cell	145Ah cell	190Ah cell	100Ah cell	175Ah cell
Dimension / mm	Height *	208	263	263	208	263
	Width	130	130	165	130	165
	Thickness	50	50	50	50	50
Mass* / kg		2.77	3.55	4.62	2.79	4.65
Capacity / Ah	Nominal	122	161	205	110	183
	Rated	110	145	190	100	175
Specific energy / Wh/ kg	Nominal	163	168	164	146	146
	Rated	147	151	152	133	139
Note		Same size as 100Ah cell	New size (Foot print is same as 100Ah cell. Height is same as 175Ah cell.)	Same size as 175Ah cell	—	—

*w/o terminal

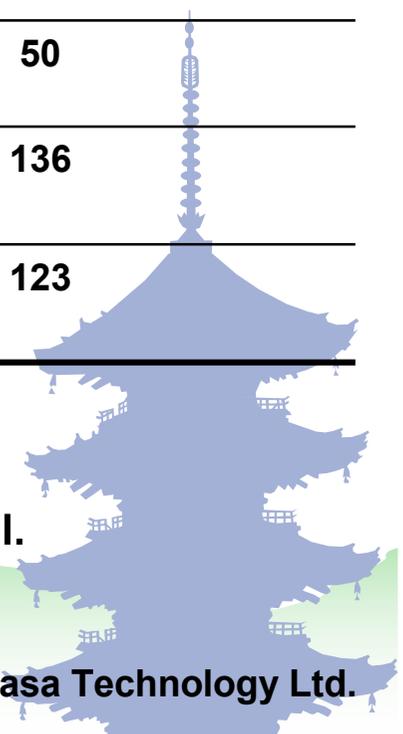


Target specifications of the next generation cells

Item		Next generation cell, LEO type	(Ref.) Heritage cell (Gen. 2)
		51Ah cell	50Ah cell
Dimension / mm	Height *	123	123
	Width	130	130
	Thickness	50	50
Mass* / kg		1.52	1.50
Capacity / Ah	Nominal	57	55
	Rated	51	50
Specific energy / Wh/kg	Nominal	139	136
	Rated	124	123

*w/o terminal

Electrode thickness of next gen. 51Ah cell is thinner than heritage cell.
This cell will be suitable for LEO application.



Appearance of the cells



Heritage (Gen. 2)
50Ah cell

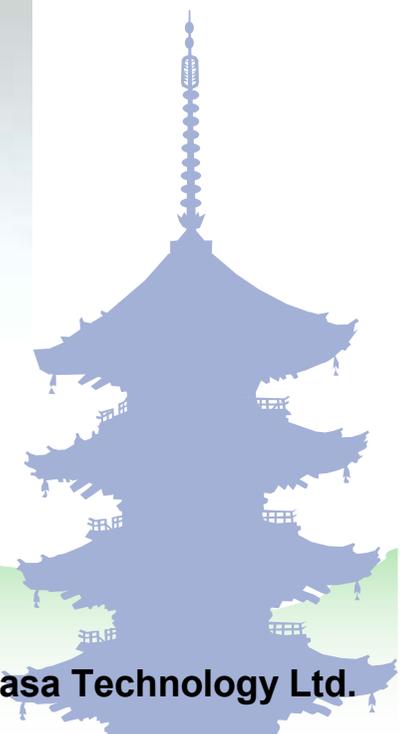
Next Generation
51Ah cell

Heritage (Gen. 2)
100Ah cell

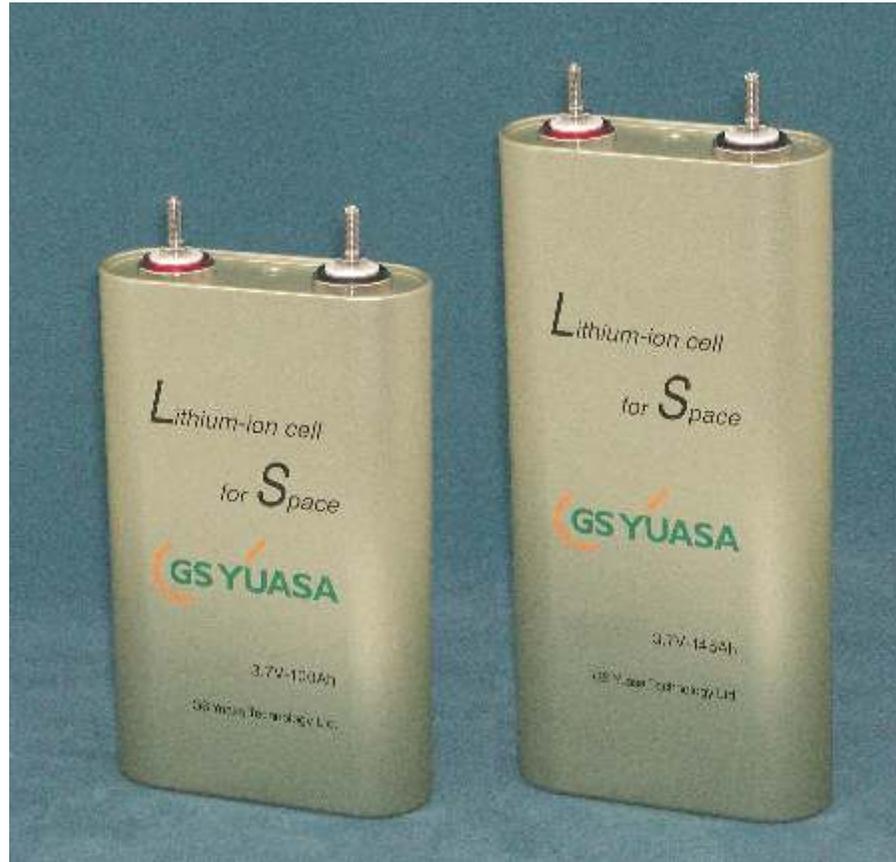
Next Generation
110Ah cell

Heritage (Gen. 2)
175Ah cell

Next Generation
190Ah cell

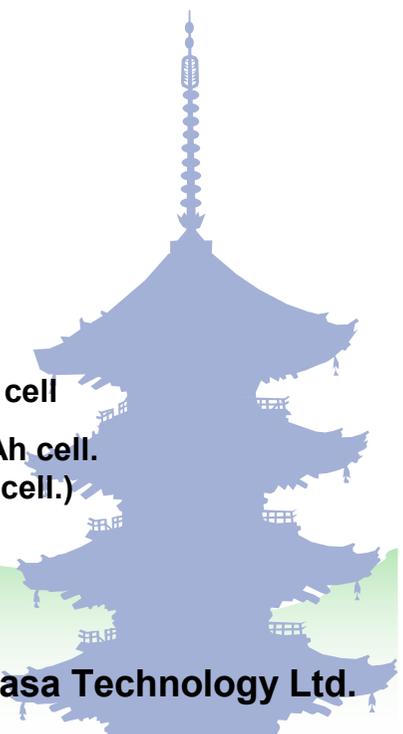


Appearance of the cells



Heritage 100Ah cell
&
Next Gen. 110Ah cell

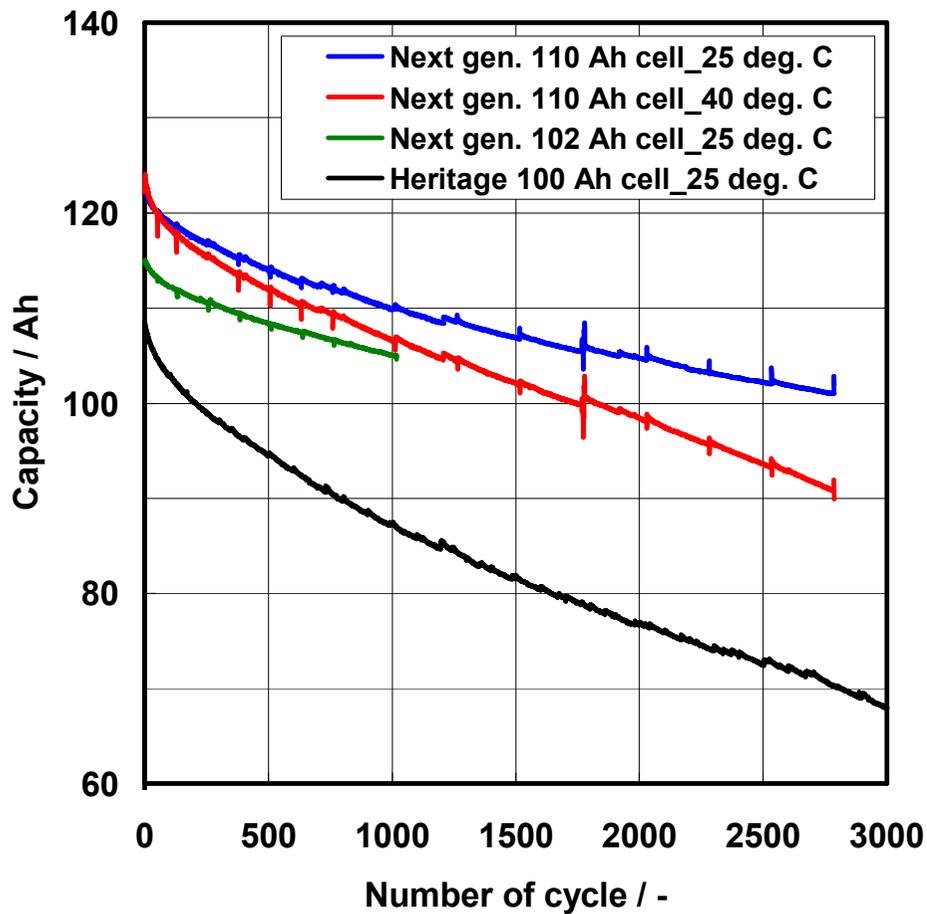
New size, next generation 145Ah cell
(Foot print is same as heritage 100Ah cell.
Height is same as heritage 175Ah cell.)



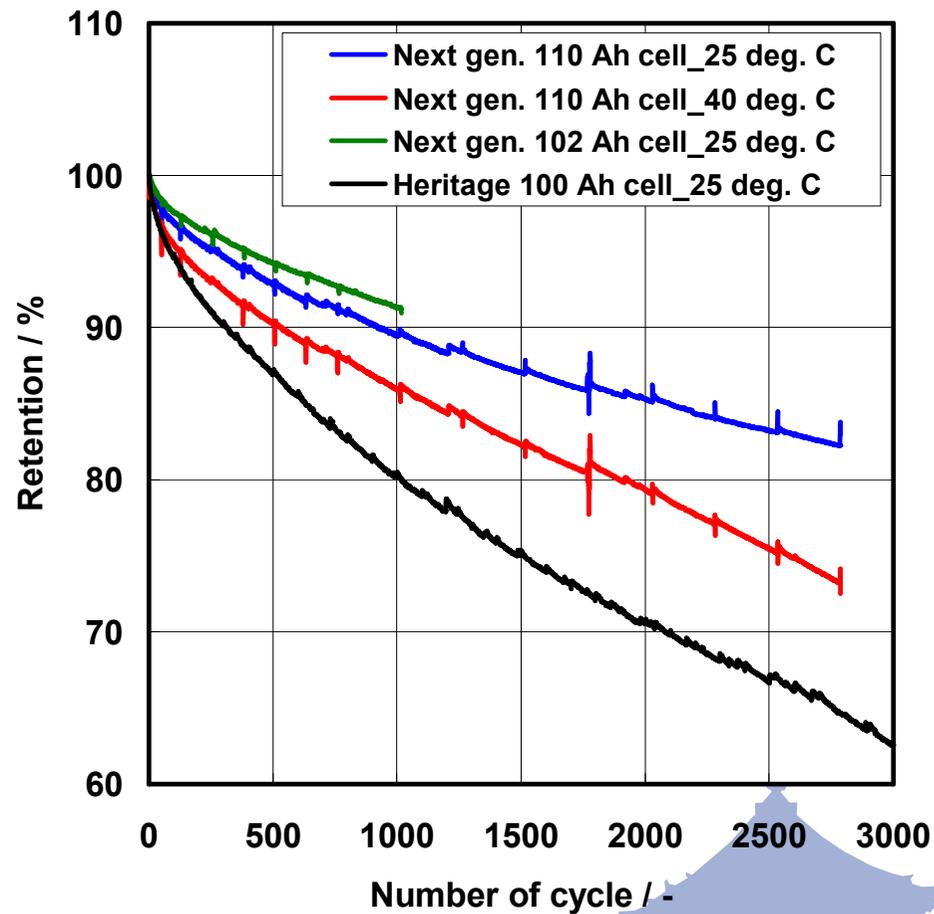
100% DOD cycle life performance test

Table Test condition of 100% DOD cycle life test.

Cell	Condition
Next generation 110Ah cell	Charge: 0.5CA (55A), 4.10V, CC/CV, 4hr Discharge: 0.91CA (100A) to 2.75V
Heritage (Gen. 2) 100Ah cell	Charge: 0.5CA (50A), 3.98V, CC/CV, 4hr Discharge: 1CA (100A) to 2.75V



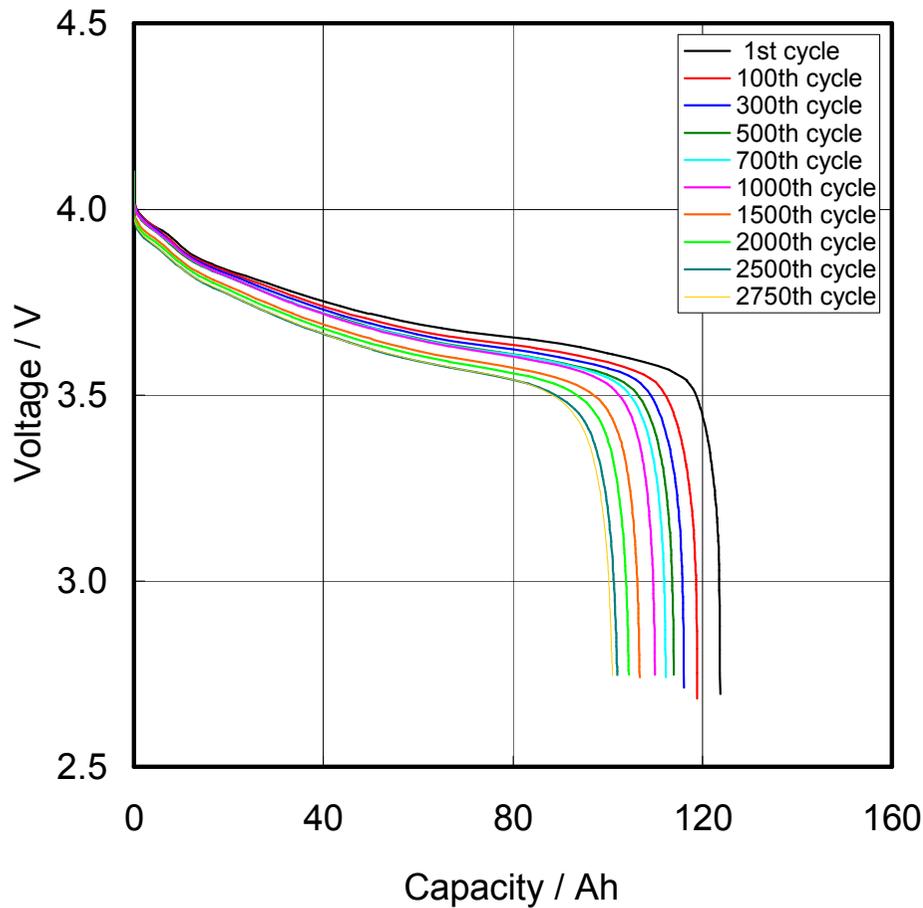
(a) Capacity



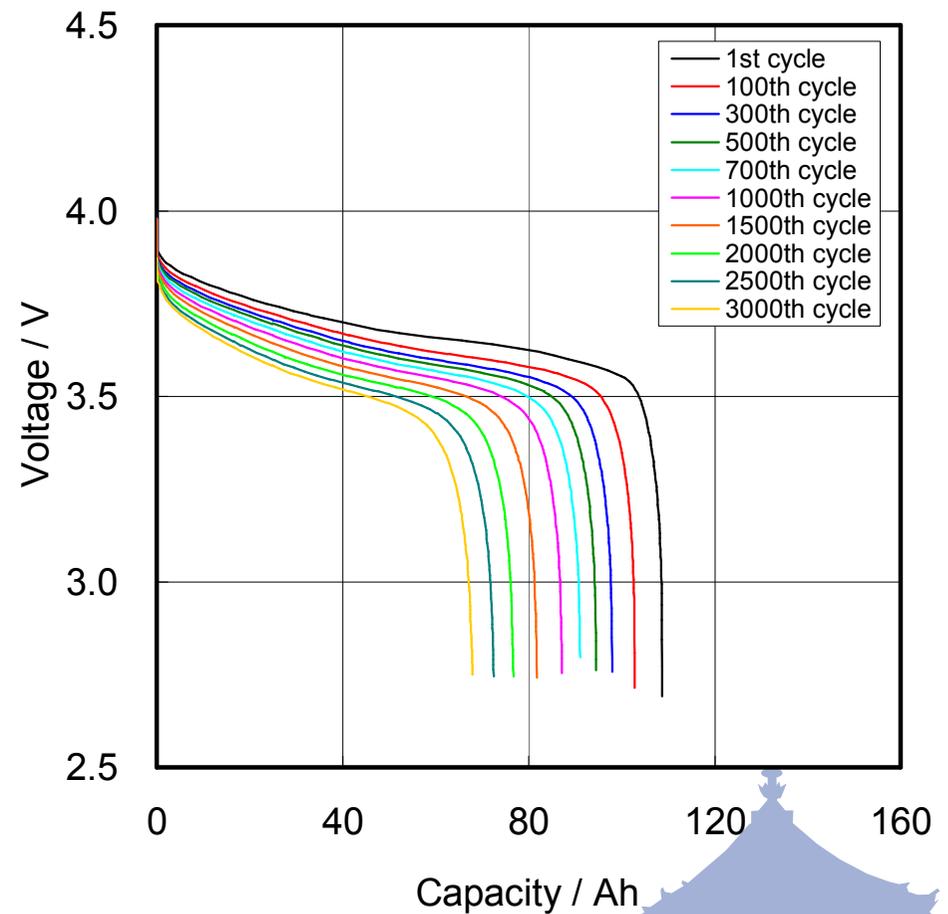
(b) Retention

Fig. Change in discharge capacity during 100% DOD cycle life test

This data was obtained in cooperation with JAXA



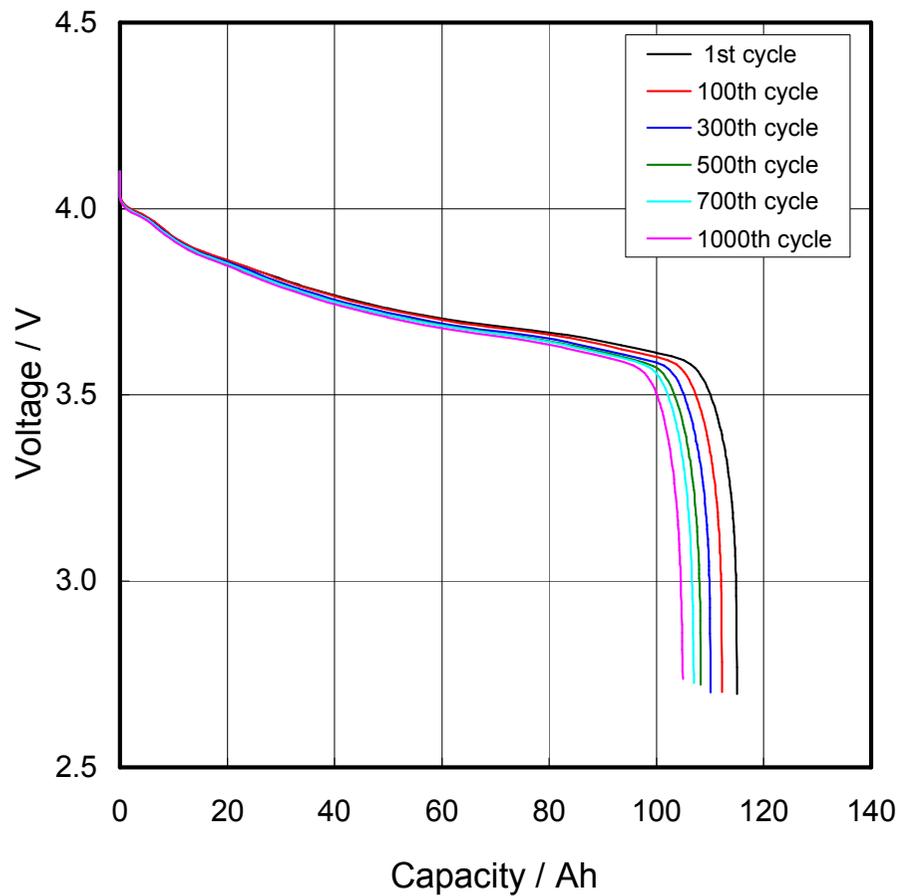
(a) Next generation 110Ah cell



(b) Heritage (Gen. 2) 100Ah cell

Fig. Discharge performance of the next generation cell and heritage cell (Gen. 2)

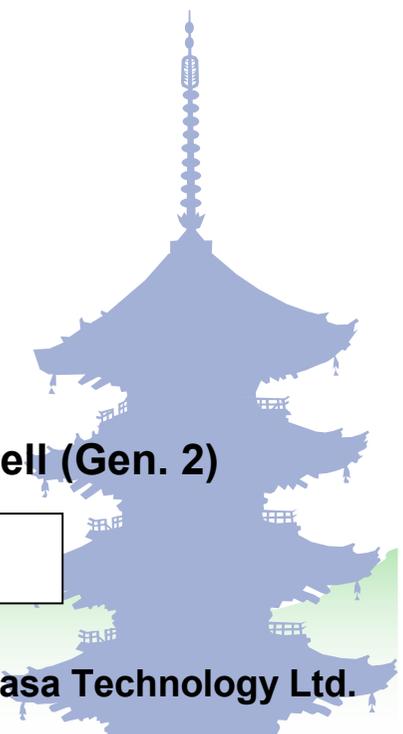
This data was obtained in cooperation with JAXA



(c) Next generation 102Ah cell

Fig. Discharge performance of the next generation cell and heritage cell (Gen. 2)

This data was obtained in cooperation with JAXA



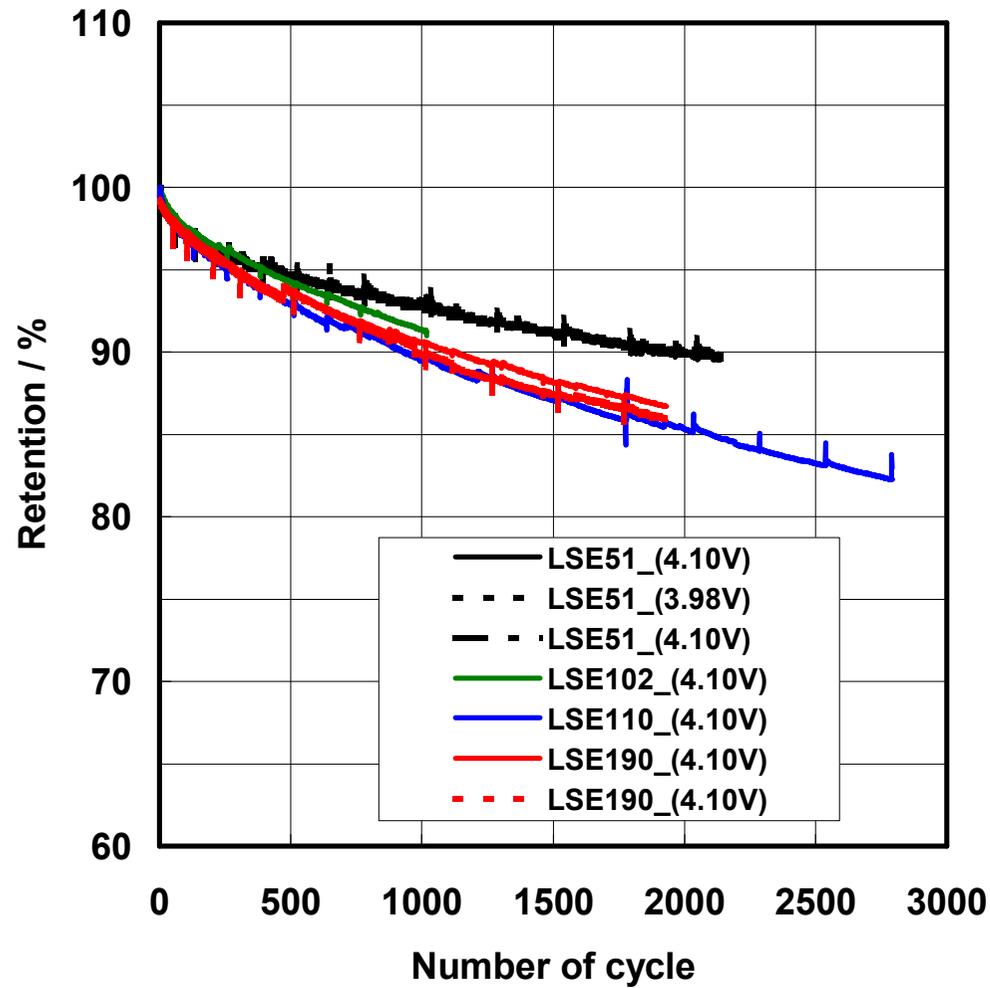
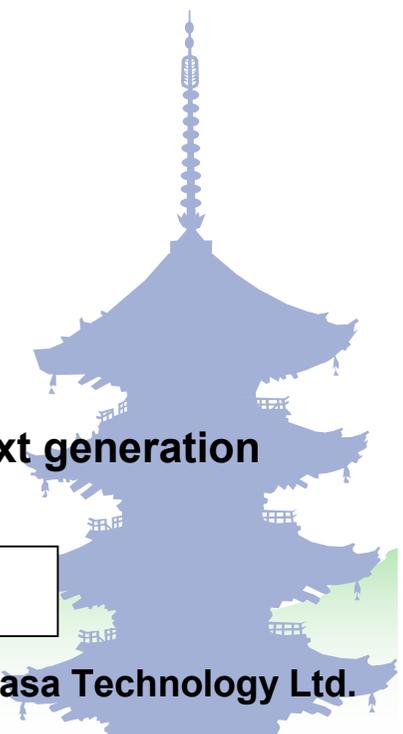
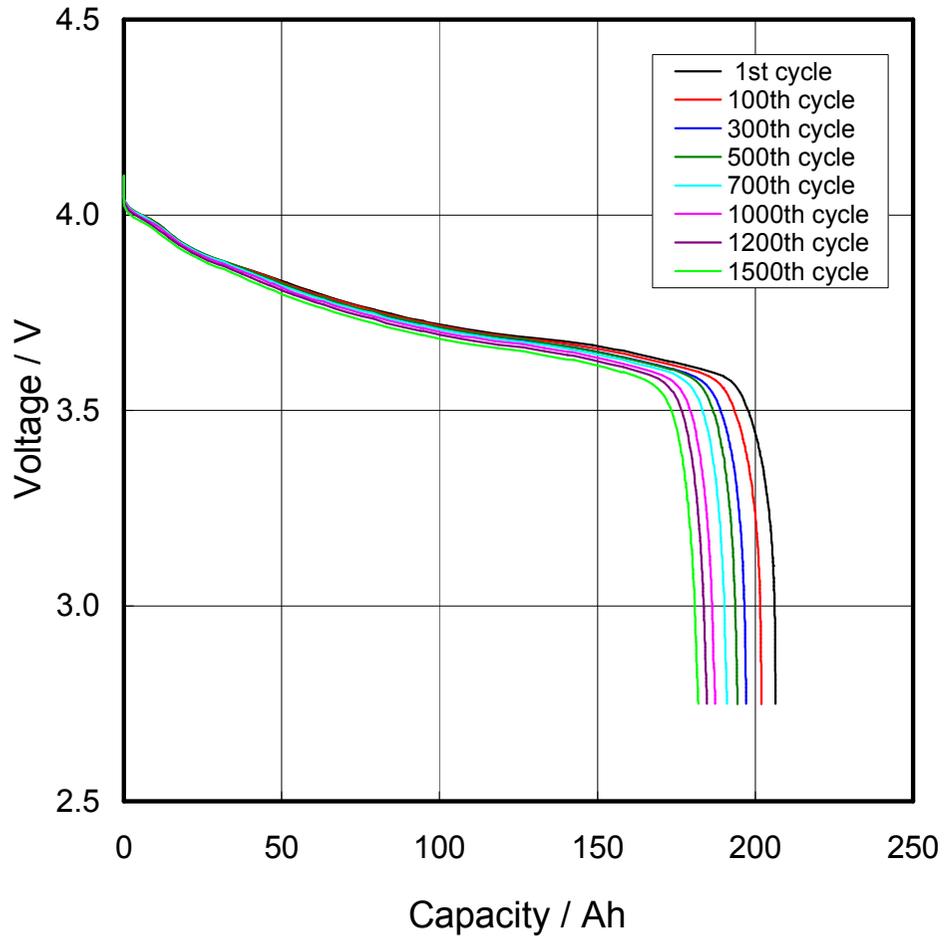


Fig. Change in discharge capacity for standard type and LEO type next generation cells during 100% DOD cycle life test

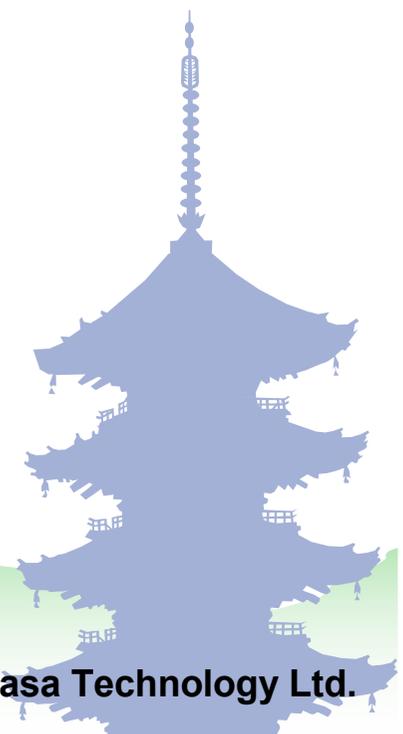
This data was obtained in cooperation with JAXA

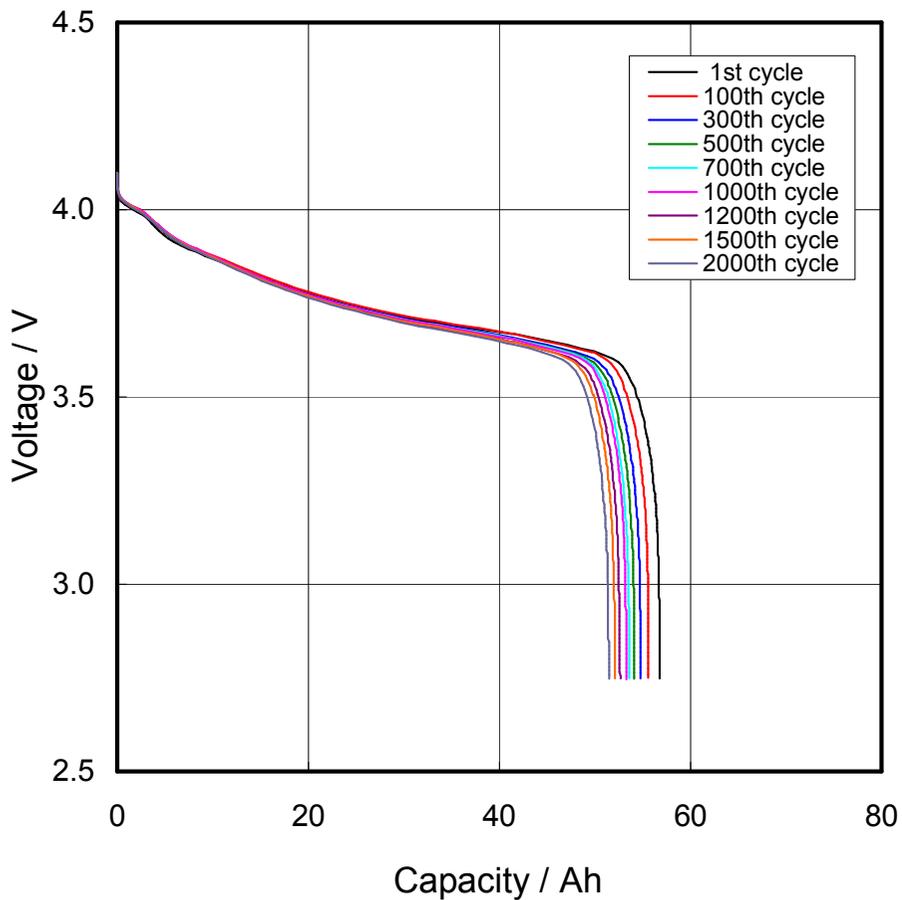




LSE190

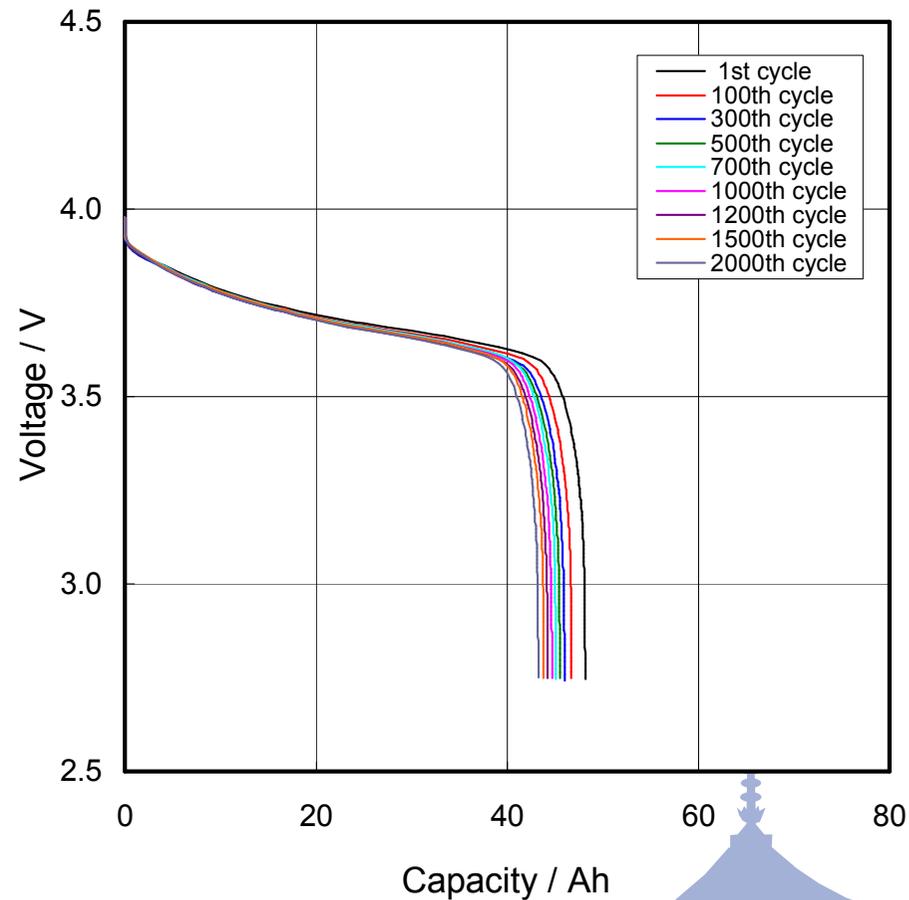
Fig. Discharge performance of LSE190



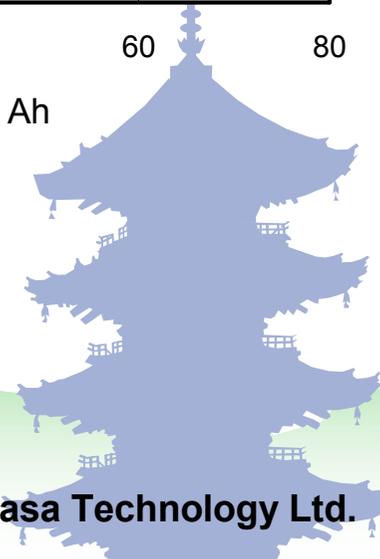


LSE51(Charge at 4.10V)

Fig. Discharge performance of LSE51



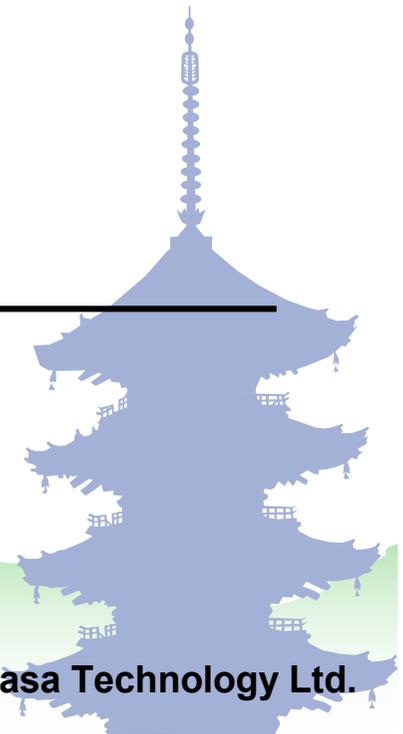
LSE51(charge at 3.98V)



80% DOD cycle life performance test

Table Test condition of 80% DOD cycle life test.

Cell	Condition
Next generation 110Ah cell	<u>Initial charge condition</u>
	Charge : 0.2CA (22A), 4.10V, CC/CV, 8hr
	<u>Cycle condition</u>
	Discharge : 0.67CA (74A) for 1.2hr Charge : 0.2CA (22A), 4.10V, CC/CV, 11.4hr
Heritage (Gen. 2) 100Ah cell	<u>Initial charge condition</u>
	Charge : 0.2CA (20A), 3.98V, CC/CV, 8hr
	<u>Cycle condition</u>
	Discharge : 0.5CA (50A) for 1.6hr Charge : 0.5CA (50A), 3.98V, CC/CV, 3.6hr



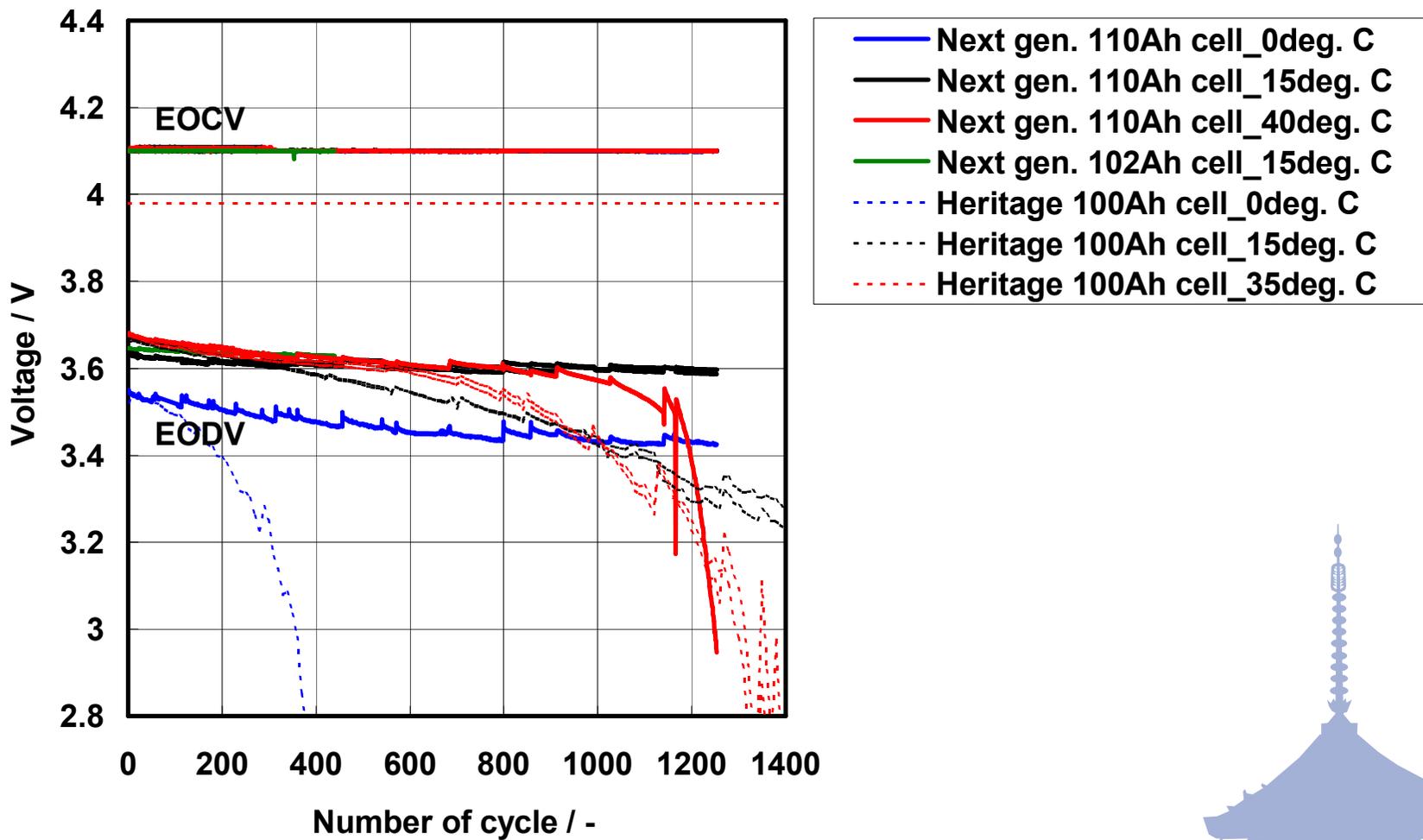
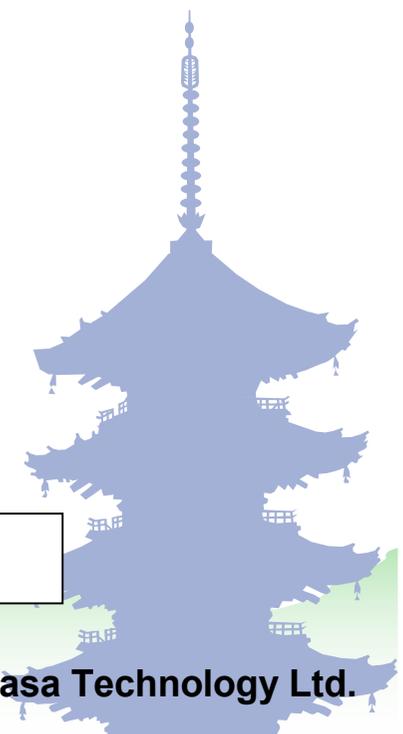


Fig. Changes in EOCV and EODV during 80% DOD cycle life test

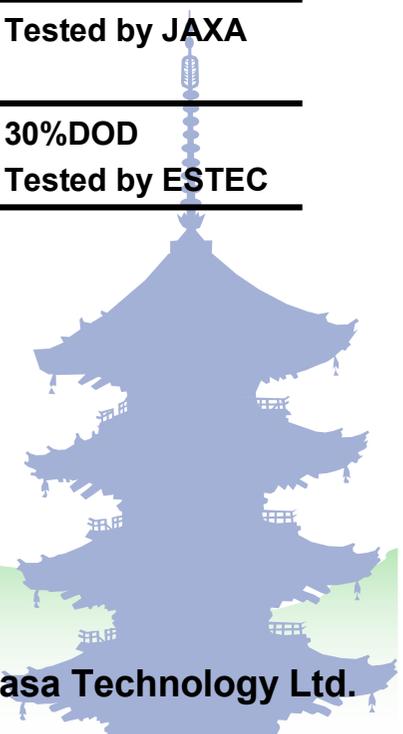
This data was obtained in cooperation with JAXA



40% DOD cycle life performance

Table Test condition of 40% DOD cycle life test.

Cell		Condition	Note
LSE51A (Next generation, LEO type)	E24	Charge: 0.5CA(25A), 3.98V, CC/CV, 1hr, 20deg. C Discharge: 0.8CA(40A) for 0.5hr, 20deg. C	
MEL100I (Heritage (Gen. 2))	E06, 07, 08, 09, 10	Charge: 0.5CA(50A), 3.95V, CC/CV, 1hr, 15deg. C Discharge: 0.8CA(80A) for 0.5hr, 15deg. C	Tested by JAXA
MEL100I (Heritage (Gen. 2))	S/N047, 048, 049	Charge: 0.25CA(25A) , 3.95V, CC/CV, 85min, 20deg. C Discharge: 0.6CA(60A) for 0.5hr, 20deg. C	30%DOD Tested by ESTEC



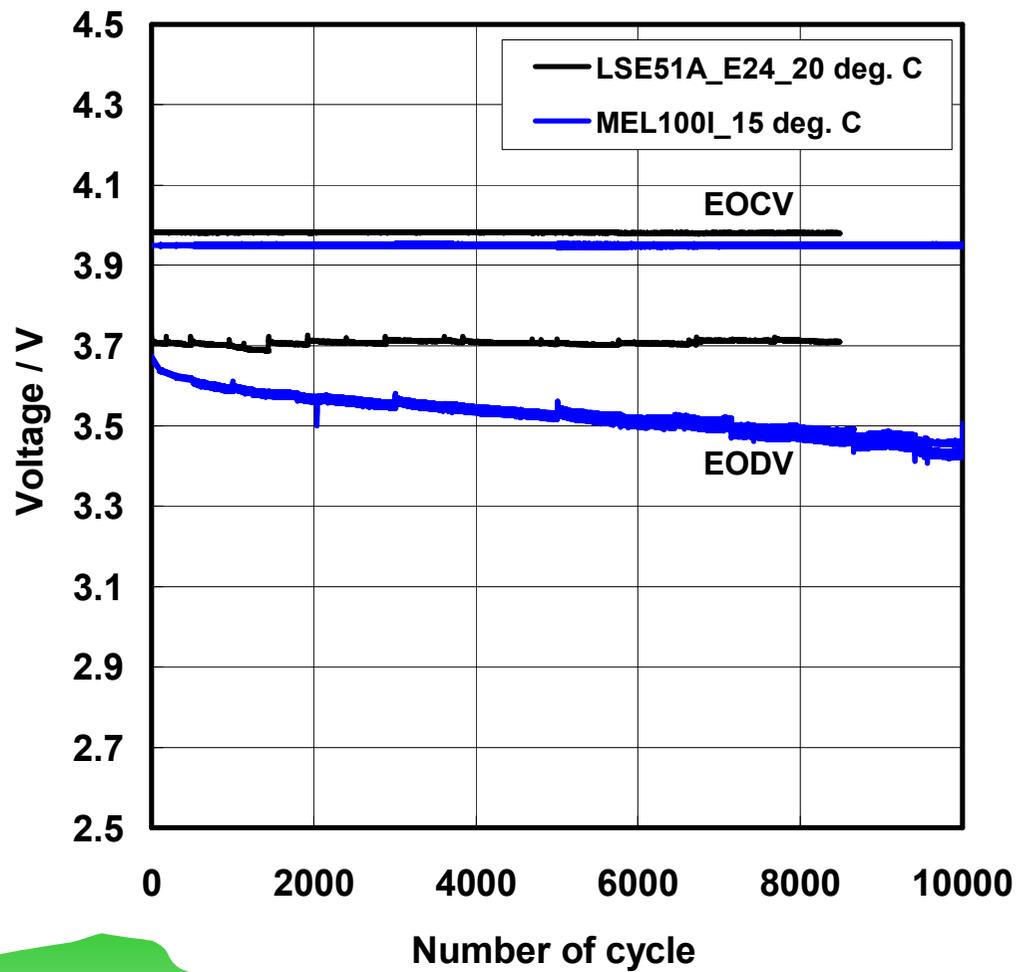
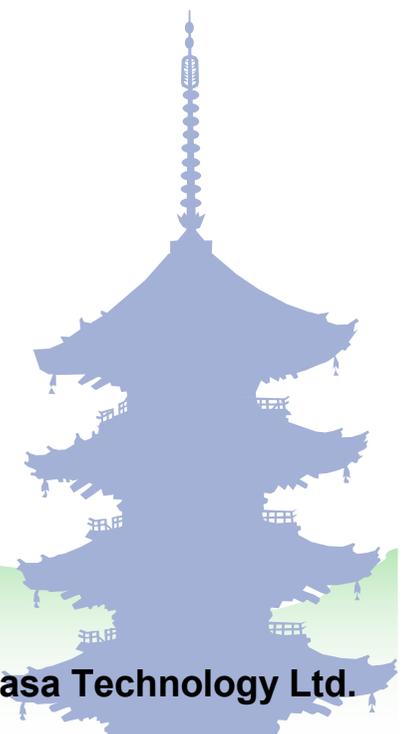


Fig. Changes in EOCV and EODV during 40%DOD cycle life test.

Test data of MEL100I was obtained by JAXA.



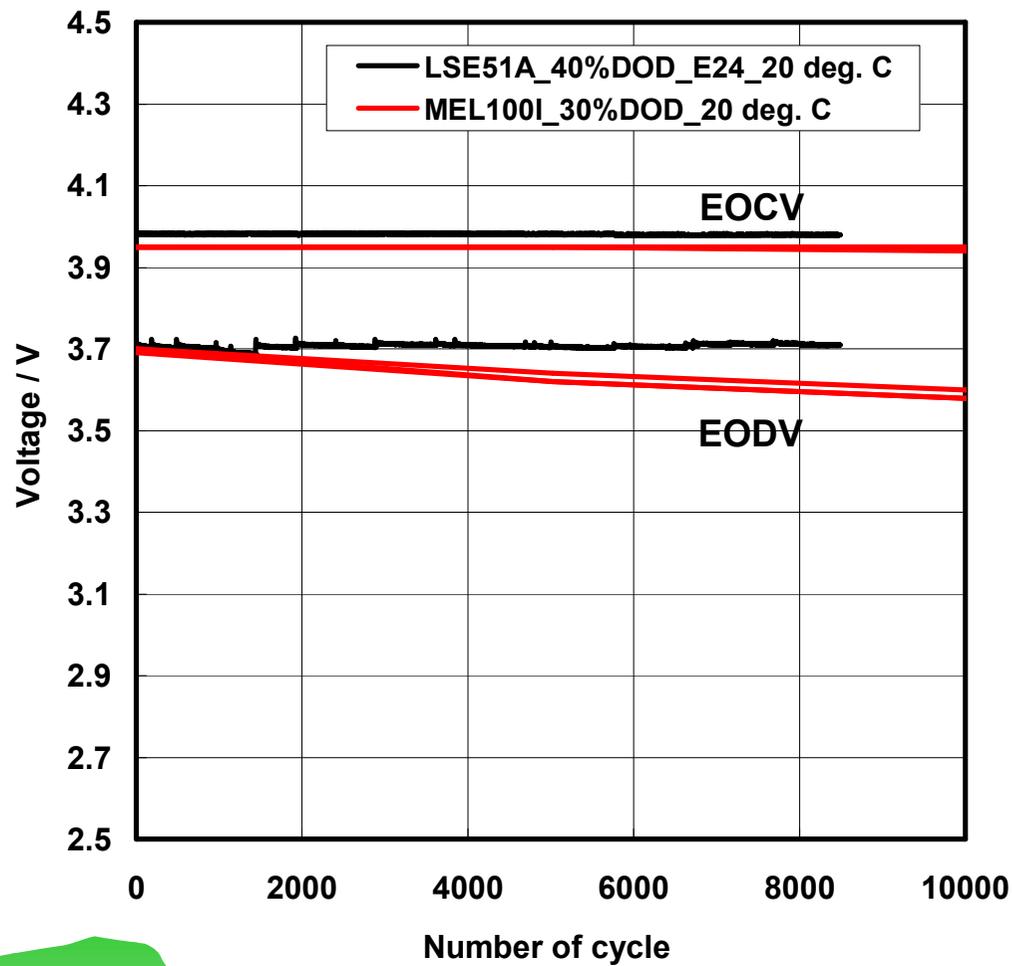
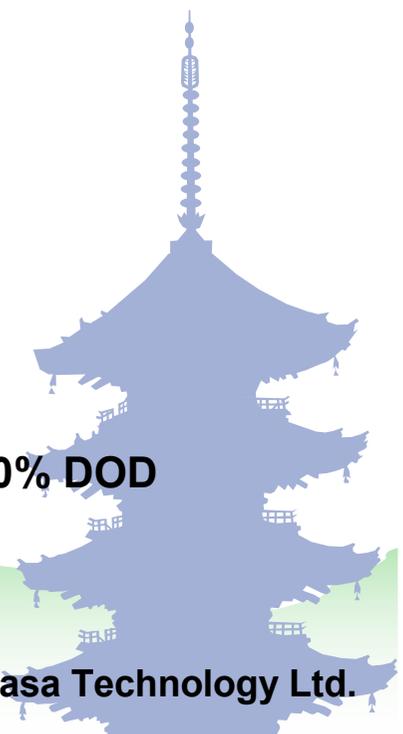


Fig. Changes in EOCV and EODV during 40%DOD(LSE51A) and 30% DOD (MEL100I) cycle life tests.

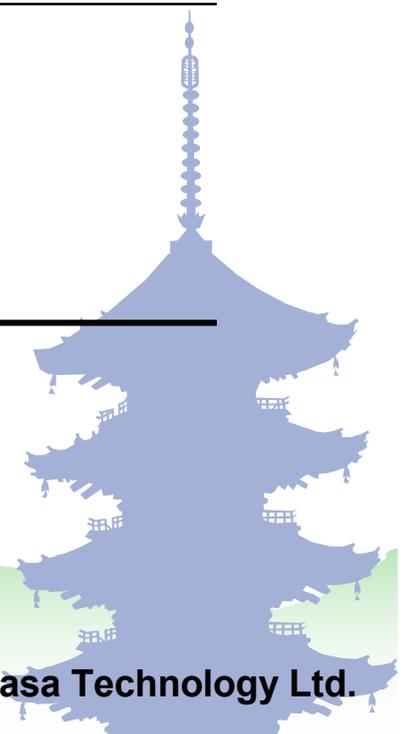
Test data of MEL100I was provided by ESTEC.

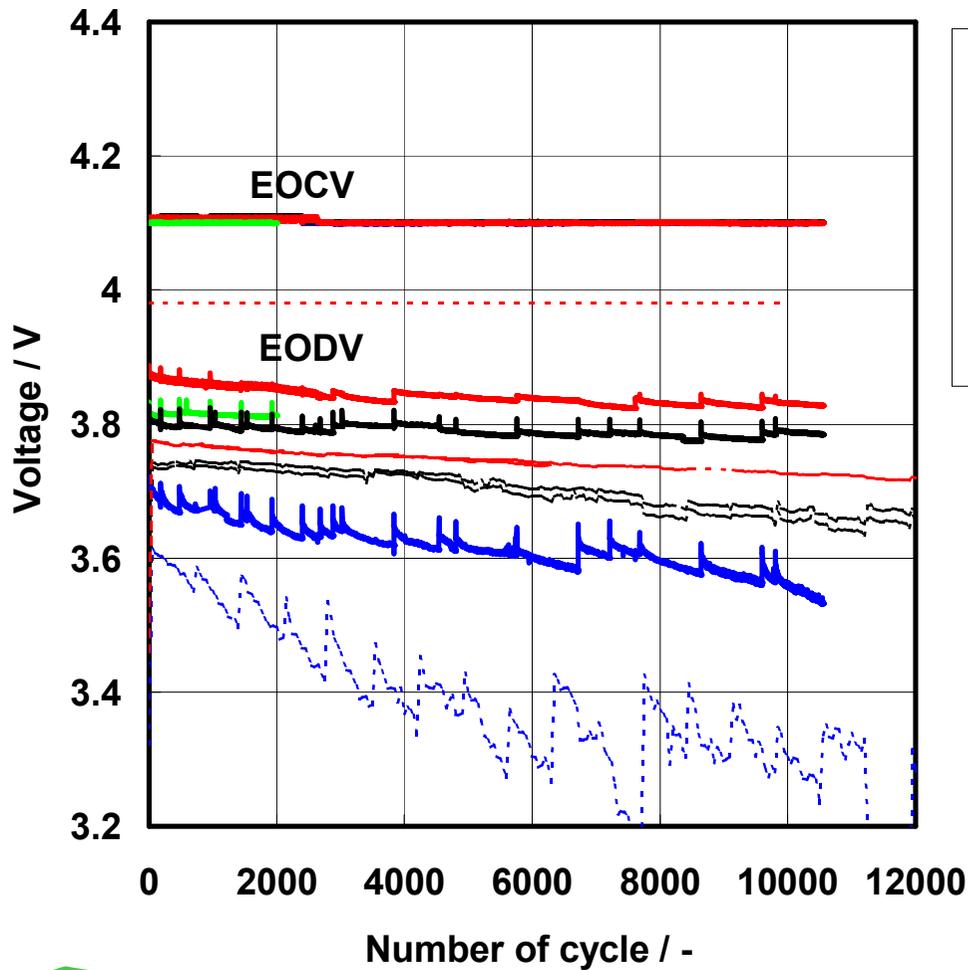


25% DOD cycle life performance test

Table Test condition of 25% DOD cycle life test.

Cell	Condition
Next generation 110Ah cell	<u>Initial charge condition</u>
	Charge : 0.2CA (22A), 4.10V, CC/CV, 8hr
	<u>Cycle condition</u>
	Discharge : 0.5CA (55A) for 0.5hr Charge : 0.3CA (33A), 4.10V, CC/CV, 1.0hr
Heritage (Gen. 2) 100Ah cell	<u>Initial charge condition</u>
	Charge : 0.2CA (20A), 3.98V, CC/CV, 8hr
	<u>Cycle condition</u>
	Discharge : 0.5CA (50A) for 0.5hr Charge : 0.5CA (50A), 3.98V, CC/CV, 0.55hr

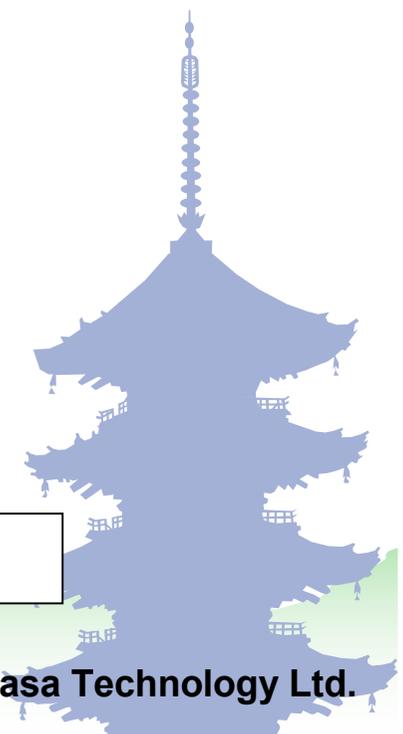


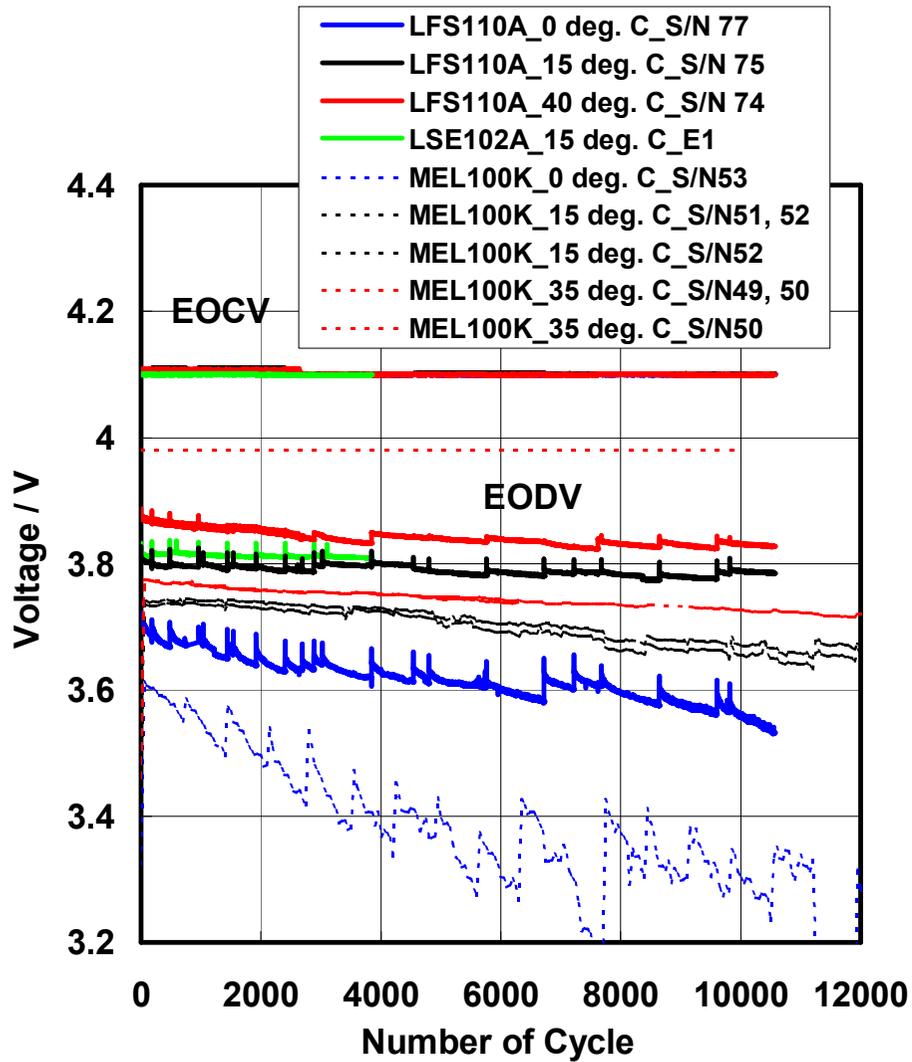


- Next gen. 110Ah cell_0deg. C
- Next gen. 110Ah cell_15deg. C
- Next gen. 110Ah cell_40deg. C
- Next gen. 102Ah cell_15deg. C
- - - Heritage 100Ah cell_0deg. C
- - - Heritage 100Ah cell_15deg. C
- - - Heritage 100Ah cell_35deg. C

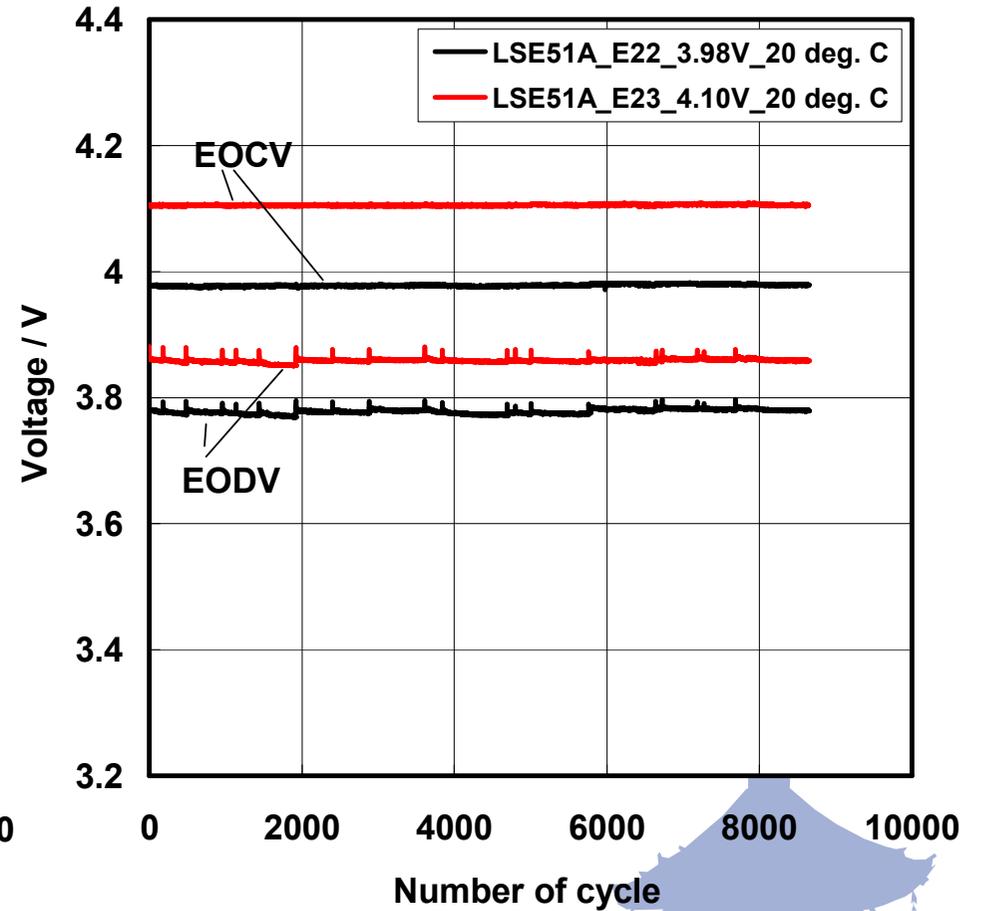
Fig. Changes in EOCV and EODV during 25% DOD cycle life test

This data was obtained in cooperation with JAXA





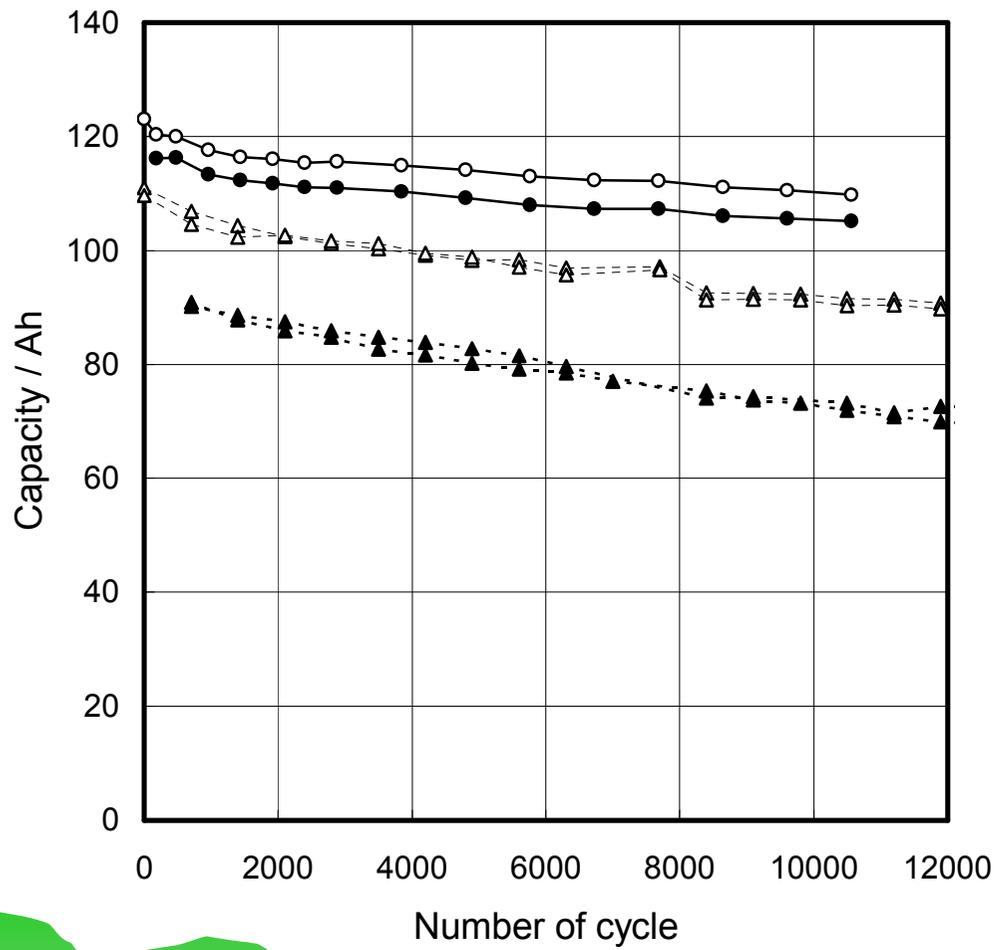
(a) LFS110 (Next generation, standard)



(b) LSE51 (Next generation, LEO type)

Fig. Changes in EOCV and EODV during 25% DOD cycle life test.

This data was obtained in cooperation with JAXA



Note:
 Cap means periodically checked capacity with longer charge and C/5 discharge shown as follows.
 <Capacity check condition>
 LFS110
 Charge: 0.2CA(22A), 4.10V, CC/CV, 8hr
 Discharge : 0.2CA (22A) to 2.75V

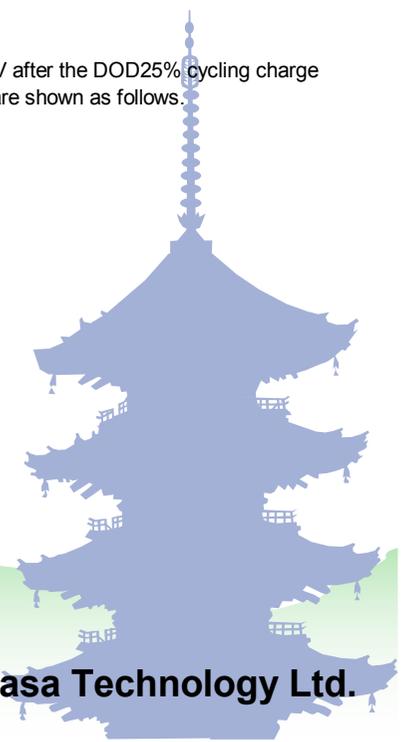
MEL100K
 Charge: 0.2CA(20A), 3.98V, CC/CV, 8hr
 Discharge : 0.2CA (20A) to 2.75V

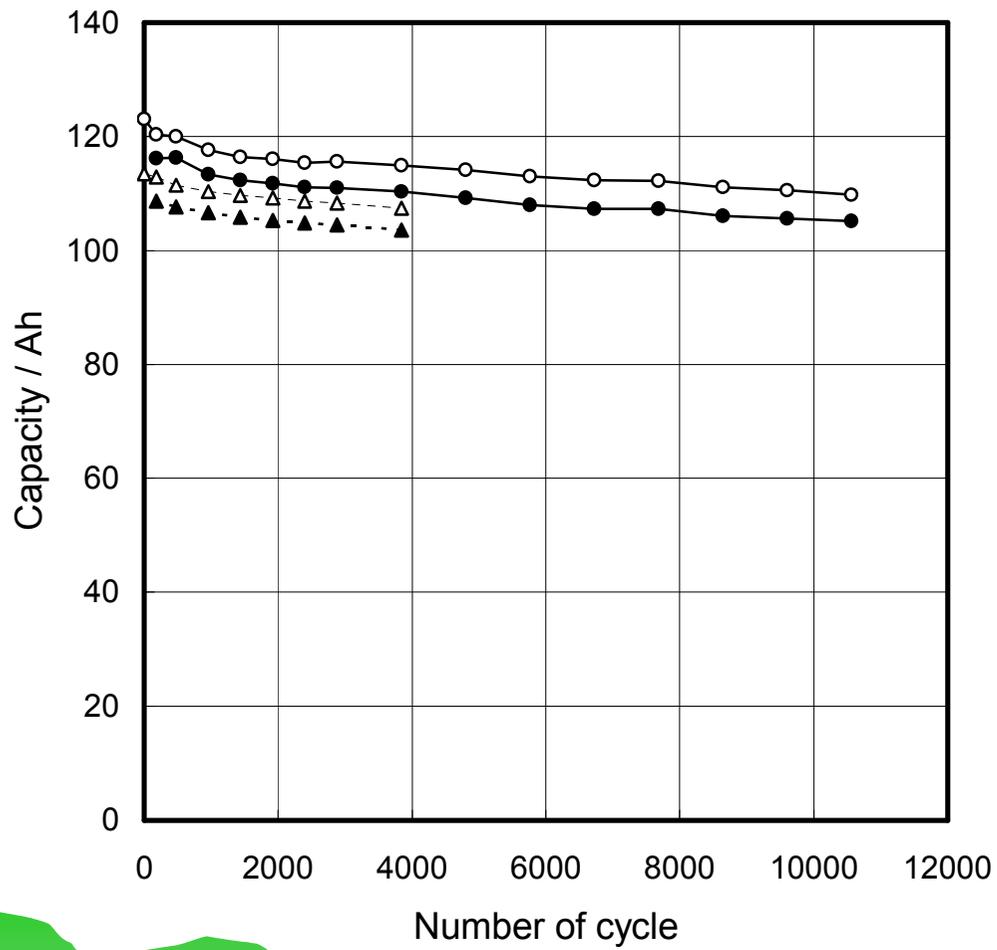
RD means Residual capacity C/5 discharge to 2.75V after the DOD25% cycling charge step. The DOD25% cycling condition of each cells are shown as follows.

<DOD25% cycling condition>
 LFS110
 Charge : 0.3CA (33A), 4.10V, CC/CV, 1hr
 Discharge : 0.5CA (55A) for 0.5hr

MEL100K
 Charge : 0.5CA (50A), 3.98V, CC/CV, 0.55hr
 Discharge : 0.5CA (50A) for 0.5hr

**Fig. Changes in Capacity during 25% DOD cycle life test.
 (Next gen vs. MEL100K)**





Note:
 Cap means periodically checked capacity with longer charge and C/5 discharge shown as follows.
 <Capacity check condition>
 LFS110
 Charge: 0.2CA(22A), 4.10V, CC/CV, 8hr
 Discharge : 0.2CA (22A) to 2.75V

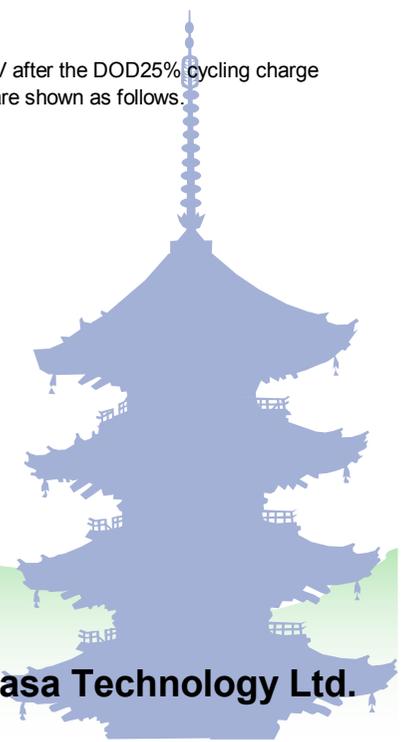
LSE102A
 Charge: 0.196CA(20A), 4.10V, CC/CV, 16hr
 Discharge : 0.196CA (20A) to 2.75V

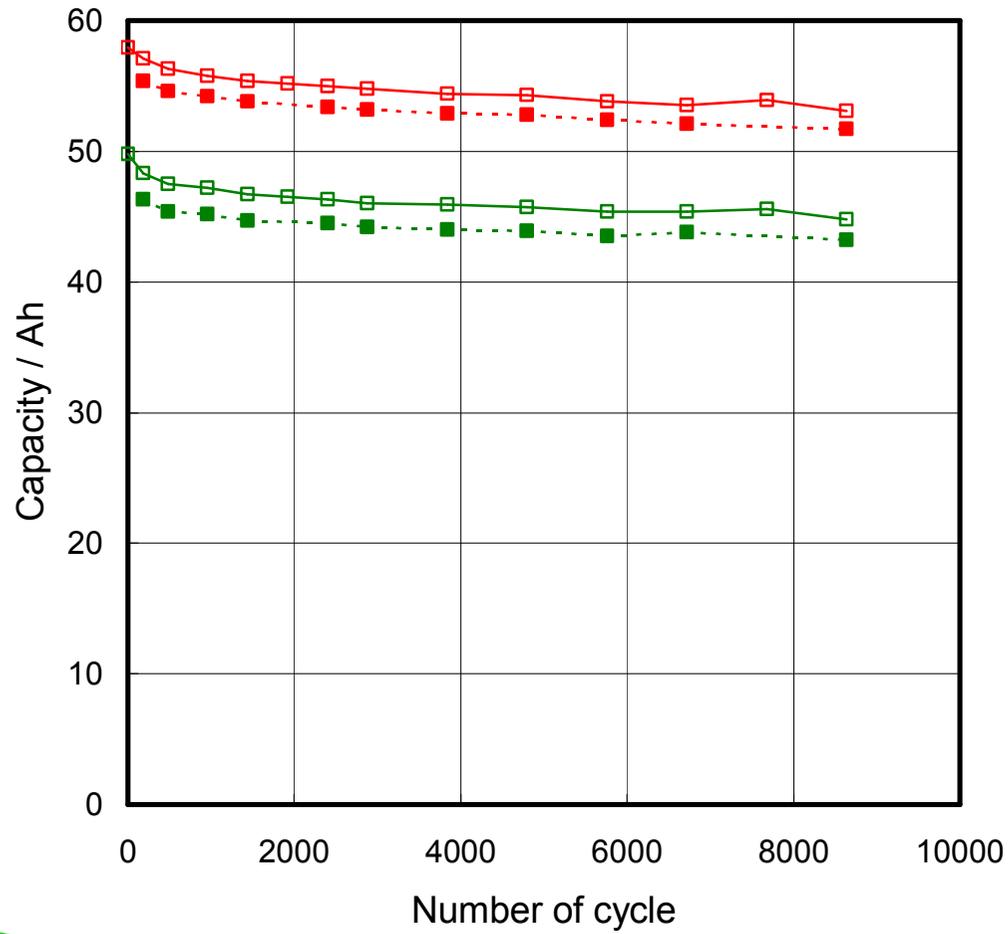
RD means Residual capacity C/5 discharge to 2.75V after the DOD25% cycling charge step. The DOD25% cycling condition of each cells are shown as follows.

<DOD25% cycling condition>
 LFS110
 Charge : 0.3CA (33A), 4.10V, CC/CV, 1hr
 Discharge : 0.5CA (55A) for 0.5hr

LSE102A
 Charge : 0.32CA (33A), 4.10V, CC/CV, 1hr
 Discharge : 0.54CA (55A) for 0.5hr

**Fig. Changes in Capacity during 25% DOD cycle life test.
 (Next gen vs. LSE102A)**





Note:
 Cap means periodically checked capacity with longer charge and C/5 discharge shown as follows.
 <Capacity check condition>
 LSE51A E23
 Charge: 0.2CA(10A), 4.10V, CC/CV, 8hr at 15 deg.C
 Discharge : 0.2CA (10A) to 2.75V at 15 deg.C

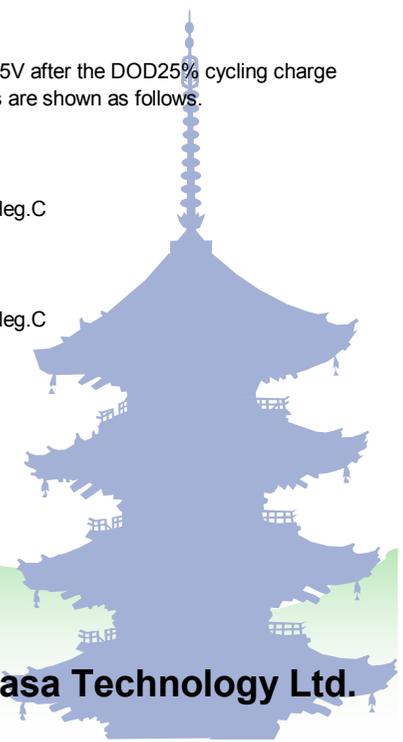
LSE51A E22
 Charge: 0.2CA(10A), 3.98V, CC/CV, 8hr at 15 deg.C
 Discharge : 0.2CA (10A) to 2.75V at 15 deg.C

RD means Residual capacity C/5 discharge to 2.75V after the DOD25% cycling charge step. The DOD25% cycling condition of each cells are shown as follows.

<DOD25% cycling condition>
 LSE51A E23
 Charge: 0.3CA(15A), 4.10V, CC/CV, 1 hr at 20 deg.C
 Discharge : 0.5CA (25A) for 0.5 hr at 20 deg.C

LSE51A E22
 Charge: 0.3CA(15A), 3.98V, CC/CV, 1 hr at 20 deg.C
 Discharge : 0.5CA (25A) for 0.5 hr at 20 deg.C

**Fig. Changes in Capacity during 25% DOD cycle life test.
 (LSE51)**



Conclusion

GS Yuasa has developed the next generation cell.

- 1) Initial capacity is increased by 10% from heritage cell.**
- 2) The next generation cell showed higher capacity retention.
Capacity loss was reduced to half.**
- 3) DCR growth was reduced to half.**

The next generation cell will be a very promising power source for space applications.



Acknowledgement

JAXA has been giving insightful comments and suggestions to this development. GS Yuasa is deeply grateful to JAXA.